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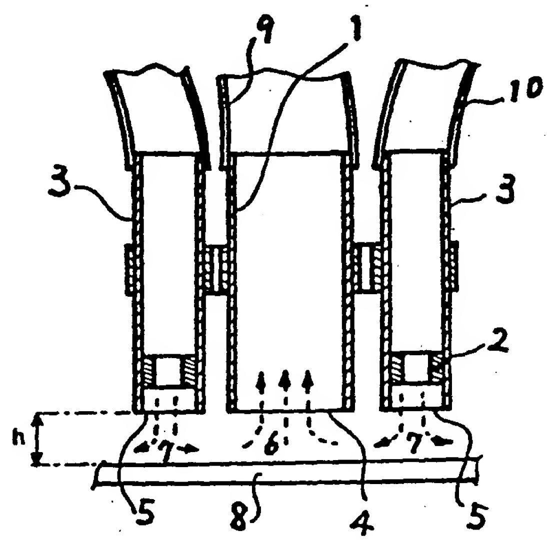
(54) Method of supporting and/or conveying a plate with fluid without physical contact.

(57) The method comprises
providing a flat surface (11) extending at opening (5) of a delivery pipe (3) to the substantially perpendicular direction to the flow direction of fluid (7) in pipe (3) and
providing a ring-shaped or annular inhaling opening (4) of a suction pipe (1) around flat surface (11),
the lower periphery of the outer wall of the outer pipe extending lower than flat surface (11) to form a stopper (12),
moving the openings (4) and (5) near the plate (8),
delivering fluid (7) from delivery pipe (3),
inhaling fluid in inhaling opening (4),
to support the plate (8), such as a semicondcutor wafer or a magnetic disc, near and at a constant distance
from flat surface (11) without physical contact therewith, and to prevent disturbance of the surrounding atmosphere by the fluid and attachment of dust on the plate (8),
or providing a flat surface (11) extending at opening (4) of an inhaling pipe (1) to the substantially perpendicular direction to the flow direction of fluid (6) in pipe (1) and
providing a ring-shaped or annular opening (5) of a delivery pipe (3) around flat surface (11),
or delivering said fluid (7) from said delivery opening (5).



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METHOD OF SUPPORTING AND/OR CONVEYING A PLATE WITH FLUID WITHOUT PHYSICAL CONTACT

1 BACKGROUND OF THE INVENTION

1-1 FIELD OF THE INVENTION

The present invention relates to a method of supporting and/or conveying a plate with fluid without physical contact. It is especially useful for supporting and/or conveying plates such as silicone wafer and floppy disc whose surface should be protected from minute scratches or contamination without physical contact in fluids such as air and conveying them if necessary in the floating state.

1-2 DESCRIPTION OF THE PRIOR ART

The inventor of the present invention proposed in Japanese patent No. 40343/1976 a method of supporting a plate with fluid without physical contact, in which a suction pipe and a delivery pipe which has an orifice near its delivery opening are assembled as the openings of suction pipe and of delivery pipe look on the same direction, a fluid is inhaled in the suction pipe and at the same time a fluid is delivered from the orifice to support a plate near the openings without physical contact.

More particularly, as shown in Figs. 1 and 2, a suction pipe 1 and a delivery pipe 3, said delivery pipe 3 being provided with an orifice 2 near the opening, are assembled as both openings 4, 5 of both pipes look on the same direction, a fluid 6 such as air is inhaled in the suction pipe 1 and at the same time a fluid 7 such as air is delivered from the orifice 2 as a jet flow, the neative pressure at the suction pipe 1 and the delivery pressure at the delivery pipe 3 being adjusted in proportion to the weight of plate to be supported, openings 4, 5 are faced below over a plate 8. Then the plate 8 can

be supported in the air without physical contact, keeping the distance between the openings 4, 5 and the flat plate 8 constant in the range of about 0.5 mm to severl mm, and the plate 8 can also be conveyed horizontally, keeping the distance h, by applying a little force to the horizontal direction. In the drawing, 9 and 10 are ducts.

In the case that the vertical delivery opening 5 is extended to the substantially perpendicular direction (horizontal) to the flow of fluid in the delivery pipe 3 to form a flat surface 11 and a plate 8 is brought under the opening 5 (Fig. 5), when the current speed of fluid 7 in the pipe 3 is constant, and when the distance of the gap h between the flat surface 11 and the upper face of plate 8 decreases, the current speed of fluid in the gap h increases, and the static pressure at the gap h decreases in accordance with Bernoulli's theorem. When this static pressure decreases to beneath atmospheric pressure and the product of this negative pressure and the area of the gap reaches to balance with the weight of plate 8, the plate 8 should float in the air without physical contact, with delivery pipe only and without suction pipe.

In the inventor's prior invention disclosed in Japanese patent application No. 71950/1985, the inventor has disclosed the test results of this theory, in which a plate was supported and/or conveyed with fluid without physical contact, by providing a flat surface 11 extending at opening 5 of a delivery pipe 3 to the substantially perpendicular direction to the flow direction of fluid 7 in said pipe 3, moving the opening 5 near a plate 8, and delivering fluid 7 from delivery pipe 3, as shown in Figs. 3 and 4.

2 SUMMARY OF THE INVENTION

In the above-mentioned prior patent application, in the case of floating plate in air, the air 7 delivered from the gap between the flat surface 11 and the plate 8 disturbs the surrounding atmosphere to raise a dust in the room. The aforementioned plate such as silicone wafer and floppy disc has been

handled in the clean room controlled to remove dust, but such a plate should be handled in the room with little disturbance of air and prevented from attaching of dust. Accordingly, the delivered fluid 7 should not be delivered from the edges of flat surface 11 and of plate 8 to the surrounding atmosphere.

The object of the present invention is to support and, at need, to convey a plate in the air (and other fluids) without physical contact, preventing the disturbance of surrounding atmosphere by the fluid delivered from the gap between the flat surface 11 and the plate 8, and preventing the attachment of dust on the plate 8.

This object can be achieved by providing suction opening(s) at the periphery of the flat surface 11 in the prior application, and inhaling the delivered fluid into the suction opening (and suction pipe). Same effect can be obtained by providing a flat surface extending at opening of an inhaling pipe to the substantially perpendicular direction to the flow direction of fluid in said inhaling pipe, and providing a ring-shaped or annular delivery opening of a delivery pipe around the periphery of the flat surface, to prevent the delivery of fluid from the gap between the flat surface and the plate to the surrounding atmosphere.

The principle of the present invention is that the fluid 7 delievered from the delivery pipe 3 forms a jet stream, passes in a little gap h between the flat surface 11 and the plate 8, and is inhaled in the suction pipe 1 as shown in Fig. 5. The section area of the gap h is extremely small compared with the section area of the delivery area of the delivery pipe 3, and the flow speed of the fluid in the gap becomes extremely high compared with the flow speed in the delivery pipe 3, and the static pressure in the gap h is lower than the atmospheric pressure, and then the plate 8 is supported in the fluid without physical contact.

If the plate 8 would come in contact with the flat surface 11, the flow speed of fluid in the delivery pipe 3 would become zero, the plate 8 would receive the delivery pressure in the pipe 3, therefore the plate 8 cannot contact with the flat surface 11.

3 BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a vertical sectional view of the essential part showing a prior art to support and float a plate with fluid without physical contact.

Fig. 2 is the bottom view of Fig. 1.

Fig. 3 is a vertical sectional view of the essential part showing the prior patent application.

Fig. 4 is the sectional view taken upon the line A - A of Fig. 3.

Fig. 5 is a vertical sectional view of the essential part showing an example of the present invention.

Fig. 6 is a vertical sectional view of the essential part showing a modification of Fig. 5.

Fig. 7 is the sectional view taken upon the line B - B of Fig. 6.

Fig. 8 is a vertical sectional view of the essential part showing another modification of Fig. 5.

Fig. 9 is a vertical sectional view of the essential part showing the other modification of Fig. 5.

Fig. 10 is the sectional view taken upon the line C - C of Fig. 9.

Fig. 11 is a vertical sectional view of the essential part showing another example of the present invention.

Fig. 12 is the sectional view taken upon the line D - D of Fig. 11.

Fig. 13 is a vertical sectional view of the essential part showing a modification of Fig. 11.

Fig. 14 is the sectional view taken upon the line E - E of Fig. 13.

Fig. 15 is a vertical sectional view of the essential part showing another example of the present invention.

Fig. 16 is the sectional view taken upon the line F - F of Fig. 15.

Fig. 17 is a vertical sectional view of the essential part showing a modification of Fig. 15.

Fig. 18 is the sectional view taken upon the line G - G of Fig. 17.

Fig. 19 is a plan view of an example of the plate handled in the example in Fig. 15,

Fig. 20 is the sectional view taken upon the line H - H of Fig. 19,

Fig. 21 is a plan view of another example of the plate handled in the example in Fig. 15,

Fig. 22 is the sectional view taken upon the line J - J of Fig. 21,

Fig. 23 is the sectional view taken upon the line K - K of Fig. 21,

Fig. 24 is a plan view of a third example of the plate handled in the example in Fig. 15,

Fig. 25 is an elevation of the essential part showing an other example of the present invention, a portion of the structure being broken away for the purpose of illustration,

Fig. 26 is the elevation of the essential part showing a modification of Fig. 25, a portion of the structure being broken away for the purpose of illustration,

Figs. 27 and 28 are the sectional views taken upon the line L - L of Fig. 26,

Fig. 29 is the vertical sectional view of the essential part for illustrating the action and the effect of the present invention,

and Fig. 30 is a graph showing relations of the distance h between flat surface 11 and plate 8 and force F given on the plate 8 and static pressure P_2 in the delivery pipe.

4 DESCRIPTION OF THE PREFERRED EMBODIMENTS

Example 1

As shown in Fig. 5, opening 5 of a vertical delivery pipe 3 with round section is extended to the substantially perpendicular direction to form a flat surface 11, a cylindrical suction pipe 1 is provided around the delivery pipe 3, the end of which is an opening 4 around the flat surface 11, the lower periphery of the outer wall of the suction pipe 1 is extended several mm to 20 mm lower than the flat surface 11 to form a stopper 12, the delivery pipe 3 is connected to a delivery opening (not shown) of fan, and the suction pipe 1 is connected to a suction opening (not shown) of fan.

Openings 4 and 5 are moved near a plate 8, air 7 is delivered from delivery pipe 3 and air 6 of the same volume as of the air 7 is inhaled in suction pipe 1. The plate 8 floats in the air without contacting with openings 4, 5 and the flat surface 11, and also can be conveyed with the whole apparatus by moving the whole apparatus.

Example 2

As shown in Figs. 6 and 7, several vertical delivery pipes 3, 3 --- are combined together and connected to a duct 10, openings 5, 5 --- of said delivery pipes 3, 3 --- are connected by large round plate, which forms a flat surface 11 substantially perpendicular to the flowing direction of air 7 in the delivery pipes 3, a suction pipe 1 is provided around the delivery pipes 3, 3, 3 --- , the lower periphery of the outer wall of the suction pipe 1 is extended several mm to 20 mm lower than the flat surface 11 to form a stopper 12, the duct 10 is connected to a delivery opening (not shown) of fan, and the suction pipe 1 is connected to a suction opening (not shown) of fan.

Openings 4 and 5 are moved near a plate 8, air 7 is delivered from delivery pipes 3, 3 --- and air 6 of not less volume than of the air 7 is inhaled in suction pipe 1. The plate 8 floats in the air without contacting with openings 4, 5 and the flat surface 11, and also can be conveyed with the whole apparatus by moving the whole apparatus.

Example 3

As shown in Fig. 8, opening 4 of a vertical suction pipe 1 with round section is extended to form a flat surface 11 substantially perpendicular to the flowing direction of fluid 6 in the suction pipe 1, a cylindrical delivery pipe 3 is provided around the lower part of said suction pipe 1, the lower periphery of the outer wall of the delivery pipe 3 is extended several mm to 20 mm lower than the flat surface 11 to form a stopper 12, the delivery pipe 3 is connected to a delivery opening (not shown) of fan, and the suction pipe 1 is connected to a suction opening (not shown) of fan.

The flat surface 11 is moved near a plate 8, air 7 is delivered from delivery pipe 3 and air 6 of the same volume as of the air 7 is inhaled in suction pipe 1. The plate 8 floats in the air without contacting with the flat surface 11, and also can be conveyed with the whole apparatus by moving the whole apparatus.

Example 4

As shown in Figs. 9 and 10, opening 4 of a vertical suction pipe 1 with round section is extended to form a flat surface 11 substantially perpendicular to the flowing direction of fluid 6 in the suction pipe 1, a suitable number of delivery openings 5, 5 ··· are provided near the periphery of the flat plate 11, a wall is provided outside of the suction pipe 1 and upon the flat plate 11 to form a torus delivery pipe 3, the lower periphery of the pipe wall of the delivery pipe 3 is extended several mm to 20 mm lower than the flat surface 11 to form a stopper 12, the delivery pipe 3 is connected to a delivery opening (not shown) of fan, and the suction pipe 1 is connected to a suction opening (not shown) of fan.

The flat surface 11 is moved near a plate 8, air 7 is delivered from delivery pipe 3 and the delivered air is inhaled in suction pipe 1 (air 6). The plate 8 floats in the air without contacting with the opening 4 and the flat surface 11, and also can be conveyed with the whole apparatus by moving the whole apparatus.

Even when the two faces of the plate 8 are prohibited physical contact, the edge of the plate is allowed to contact to other solids in many cases. In this case, the plate 8 supported below the flat surface is supported at its edge by the stopper 12, the plate 8 can be revolved with the rotation of whole apparatus, to be supported vertically, and also can be revolved further to be supported horizontally upon the flat surface 11 without physical contact.

The flow directions of airs 7 and 6 can be reverse as shown in Figs. 5 and 8.

In the above Examples 1 to 4, during supporting and conveying the plate 8 under the flat surface 11 without physical contact and at a constant distance from the flat surface 11, and during revolving the plate with the apparatus to verticl position or to the upperside of the flat surface, the supporting of the plate 8 has a risk to become unstable, namely, the plate 8 vibrates up and down by a little fluctuation of fluid's flow or of conveying speed. Then the distance h of the flat surface 11 and the plate 8 fluctuates, fluid 7 can not flow in the gap between the flat surface 11 and the plate 8, to fluctuate the static pressure in the gap and to contact the plate 8 and the flat surface 11.

The object of the following Examples 5 and 6 are to delete the above disadvantage, to prevent the unstable vibration of the plate 8 in the supporting and conveying process, and to support or convey the plate 8 and further to revolve the plate 8 to the vertical position and to the horizontal position upon the flat surface 11 without physical contact. This object is achieved by cutting channels radially on the flat surface 11, according to the following Examples 5 and 6.

Example 5

As shown in Figs. 11 and 12, opening 5 of a vertical delivery pipe 3 with round section is extended to the substantially perpendicular direction to form a flat surface 11, the flat surface 11 is provided with many channels 13, 13, 13 --- from the opening 5 to the outer periphery, a suction pipe 1 is provided around the delivery pipe 3, the end of which is an opening 4 around the

flat surface 11, the lower periphery of the outer wall of the torus suction pipe 1 is extended several mm to 20 mm lower than the flat surface 11 to form a stopper 12, the delivery pipe 3 is connected to a delivery opening (not shown) of fan, and the suction pipe 1 is connected to a suction opening (not shown) of fan.

When the flat surface 11 is moved near a plate 8 and air 7 is delivered from delivery pipe 3 and air 6 is inhaled in suction pipe 1, the air radially flowing in the gap of the flat surface 11 and the plate 8 is rendered uniform and stable by the channels 13, 13, 13 ··· , and the air flow is prevented to become unstable or to form aireddy in the case of decelerated flow. And the plate 8 floats stably in the air without vibrating up and down and without contacting with opening 5 and the flat surface 11, the plate keeps constant distance from the opening 5 and the flat surface 11, and further can be conveyed with the whole apparatus by moving the aparatus; or by supporting the edge of the plate 8 by the stopper 12, the plate 8 can be revolved with the rotation of whole apparatus, to be supported vertically, and also can be revolved further to be supported horizontally upon the flat surface 11 without physical contact. The flow direction of air 7 can be reverse of the arrow in Fig. 11.

Example 6

As shown in Figs. 13 and 14, opening 4 of a vertical suction pipe 1 is extended to form a flat surface 11 substantially perpendicular to the flowing direction of fluid 6 in the suction pipe, a suitable number of delivery openings 5, 5 ··· are provided near the periphery of the flat plate 11, the flat surface 11 is provided with many channels 13, 13, 13 ··· preferably from the opening 5 to the inner periphery, the channels being curved and/or inclined from the radial direction, pipe wall is provided outside of the suction pipe 1 and upon the flat surface 11 to form a delivery pipe 3, the lower periphery of the outer wall of the delivery pipe 3 is extended several mm to 20 mm lower than the flat surface 11 to form a stopper 12, the delivery pipe 3 is connected to a delivery opening (not shown) of fan, and the suction pipe 1 is connected to a suction opening (not shown) of fan.

The flat surface 11 is moved near a plate 8, air 7 is delivered from delivery pipe 3 and the delivered air is inhaled in suction pipe 1 (shown as air 6). The plate 8 floats in the air without contacting with the flat surface 11, without vibrating up and down as it rotates by the air flow along the radial and curved channels 13, 13··· , holding its relative position to the flat surface 11. The plate 8 can also be conveyed with the whole apparatus by moving the whole apparatus. The flow direction of airs 7 and 6 can be reverse as shown in Fig. 13.

In Examples 5 and 6 the shapes of section of delivery pipe 3, of section of suction pipe 1, of flat surface 11 and of stopper 12 are round, they are of course not to be limited to round shape, namely they can be elliptic, polygonal, etc.

The above examples relate to supporting and/or conveying a plate without hole, and a plate with hole as a hard disc with hole cannot be supported, as in Fig. 5, for example, when the plate 8 has a hole below the opening 5, fluid 7 cannot flow into the gap between the flat surface 11 and the plate 8, negative pressure does not produce in the gap h, and the plate can not be supported or floated in the atmosphere without physical contact.

Examples 7 and 8 has the object to delete the above disadvantage, to support and/or convey a plate with hole such as hard disc with hole without physical contact, or revolving from its horizontal state to vertical state and further to reversed horizontal state. This object is achieved by providing a ring-shaped flat surface put between a ring-shaped opening of delivery pipe and a ring-shaped opening of suction pipe (these two openings being concentric).

Example 7

As shown in Figs. 15 and 16, a ring-shaped opening 5 of a delivery pipe 3 is extended to the perpendicular direction to form a ring-shaped flat surface 11, a torus suction pipe 1 is provided, the end of which is a ring-shaped opening 4 around the flat surface 11, inner periphery of the ring-shaped opening 5 and outer periphery of the ring-shaped opening 4 are extended several mm to 20 mm lower than the flat surface 11 to form stoppers 12a, 12b, the

delivery pipe 3 is connected to a delivery opening (not shown) of fan, the suction pipe 1 is connected to a suction opening (not shown) of fan, and the inner face of divergent part of delivery pipe 3 is supported by connecting with suitable points of inner face of outer wall by connecting rods 14, 14.

Openings 4 and 5 are moved near a round plate 8 with round hole as shown in Fig. 15, positions of inner periphery 12a of the opening 5 and the hole of plate 8 are arranged, air 7 is delivered from delivery pipe 3 and the delivered air 7 is inhaled in suction pipe 1 as shown as arrow 6. The plate 8 floats in the air without contacting with openings 4, 5 and the flat surface 11, and also can be conveyed with the whole apparatus by moving the whole apparatus.

Example 8

As shown in Figs. 17 and 18, a ring-shaped opening 5 of a delivery pipe 3 is extended to both inner and outer sides substantially perpendicular to the flowing direction of fluid 7 in the delivery pipe 3 to form a ring-shaped flat surfaces 11a, 11b, a suitable number of suction openings 4a, 4a are provided near the inner periphery of the inner flat plate 11a, a suitable number of suction openings 4b, 4b··· are provided near the outer periphery of the outer flat plate 11b, a pipe wall 15 is provided inside of the delivery pipe 3 to form a cavity 1a, said suction openings 4a, 4b connecting with cavity 1a and suction pipe 1 respectively, suction pipe 1 and cavity 1a are connected with a suitable number of connecting pipe 1b, inner periphery of flat surface 11a and outer periphery of flat surface 11b are extended downwardly several mm to 20 mm lower than the flat surfaces 11a, 11b to form stoppers 12a, 12b, the delivery pipe 3 is connected with a delivery opening (not shown) of fan, and the suction pipe 1 is connected with a suction opening (not shown) of fan.

Opening 5 is moved near a round plate 8 with round hole as shown in Figs. 19 and 20, positions of inner periphery 12a of the cavity 1a and the hole of plate 8 are arranged, air 7 is delivered from delivery pipe 3 and air 6 of same volume as of air 7 is inhaled in suction pipe 1 as shown as arrows 6.

The plate 8 floats in the air without contacting with openings 4a, 4b, 5 and flat surfaces 11a, 11b, holding a constant distance from them, and also can be conveyed with the whole apparatus by moving the whole apparatus. The flow directions of airs 7 and 6 can be reverse in Examples 7, 8.

In the above Examples 7 and 8, the plate 8 is described as of round figure with round hole; but any plate of different shape such as a rectangular plate with rectangular hole as shown in Figs. 21 - 23, or a triangular plate with round hole as shown in Fig. 24 can be supported and/or conveyed in the same way by fitting the shape of flat surface 11 to the shape of the plate.

Although the above-mentioned examples can be used as the essential parts of mechanical holding and conveying systems, the following Examples 9 and 10 relates to the modifications to hold and convey a plate without physical contact by handwork.

Example 9

As shown in Fig. 25, opening 5 of a vertical delivery pipe 3 with round section is extended to the substantially perpendicular direction to form a flat surface 11, a suction pipe 1 is provided around the delivery pipe 3, the end of the outer wall of the suction pipe 1 forms an opening 4 around the flat surface 11, the lower periphery of the outer wall of the torus suction pipe 1 is extended several mm to 20 mm lower than the flat surfae 11 to form a stopper 12, the delivery pipe 3 being installed in the suction pipe 1, the suction pipe 1 is elongated to form a handle 16, delivery pipe 3 and suction pipe 1 are separated at the end of the handle 16, the delivery pipe 3 is connected with a delivery opening (not shown) of fan, and the suction pipe 1 is connected with a suction opening (not shown) of fan. The inner walls of the delivery pipe 3 and of the suction pipe 1 are preferably provied with flow-uniforming plates 17.

Handle 16 is holded by hand, the flat surface 11 is moved near a plate 8, air 7 is delivered from delivery pipe 3 and air 6 of the same volume as of the air 7 is inhaled in suction pipe 1. The plate 8 floats in the air without contacting with openings 4, 5 and the flat surface 11, and also can be conveyed

with the whole apparatus by moving the whole apparatus, or by supporting the edge of the plate 8 by the stopper 12, the plate 8 can be revolved with the rotation of whole apparatus, to support the plate 8 vertically, and also can be revolved further to support the plate 8 horizontally upon the flat surface 11 without physical contact.

Example 10

As shown in Figs. 26 and 27, opening 5 of a vertical delivery pipe 3 with round section is extended to form a flat surface 11 perpendicular to the flowing direction of fluid 7 in the delivery pipe 3, a suitable number of suction openings 4, 4 --- are provided near the outer periphery of the flat plate 11, pipe wall is provided outside of the delivery pipe 3 and upon the flat plate 11 to form a suction pipe 1, suction pipe 1 is elongated to form a handle 16, switch 19 of a fan 18 is provided at a suitable position of handle 16, the delivery pipe 3 is connected with a delivery opening (not shown) of fan 18, the suction pipe 1 is connected with a suction opening 20 of fan 18, the lower periphery of the outer wall of the suction pipe 1 is extended several mm to 20 mm lower than the flat surface 11, to form a stopper 12. The inner wall of the suction pipe 1 is preferably provided with flow-uniforming plate 17. The shape of suction openings 4, 4 --- of flat plate 11 may be modified as shown in Fig. 28, for example. A plate 8 can be supported and/or conveyed without physical contact similarly as in Example 9.

The flow directions of airs 7 and 6 can be reverse in Examples 9 and 10.

Other Examples

In the above examples, method of supporting and/or conveying a plate in the air using air as fluids 6 and 7, but a plate can be supported and/or conveyed using any gas other than air or water or any other liquid as fluids 6 and 7. Fluids 6 and 7 other than the fluid surrounding the plate 8 and the apparatus can also be used. For example, a plate 8 can be washed by using a liquid detergent as fluids 6 and 7, and thereafter dried by using air of room termperature or heated air as fluids 6 and 7.

5 ACTION OF THE PRESENT INVENTION

In the apparatus shown in Fig. 5, when a plate 8 was supported in the air under the conditions of

W	weight of plate	20 g
P_j	jet pressure of delivered fluid	10 g/cm^2
P_D	negative pressure between flat surface and plate	-40 mmAq
A_D	area of cross section of opening 5	2.84 cm^2
A_P	area of flat surface 11	17.6 cm^2,

the plate 8 was supported with 0.5 mm of the distance h between the upper surface of the plate 8 and flat surface 11.

Using the apparatus as shown in Fig. 29, the relation of suction force - F (g) or pressure force + F (g) and static pressure in the delivery pipe P_2 (mmAq) was measured.

Solid lines in Fig. 30 show relations between h and F and P_2 at the conditions of

2kR	inside diameter of delivery pipe 3	19 mm
2R	outside diameter of flat surface 11	51 mm
Ds	diameter of round plate 8	56 mm
W	weight of round plate 8	20 g
P_{20}	static pressure in the delivery pipe 3 when air 7 was introduced in the delivery pipe 3 and opening 5 was closed	350 mmAq, 450 mmAq, 550 mmAq.

The graph shows that

1) the flat surface 11 and the plate 8 can not contact, as the plate 8 receives a pressure at the point of h = 0, i. e., when the plate 8 will contact with the flat surface 11,

2) when the distance h between the both surfaces becomes about 0.3 mm, the pressure

in the gap between the both surfaces becomes negative, and this negative pressure increases as the gap h becomes large,

3) when the distance h becomes larger than about 4.3 mm, the pressure in the gap becomes plus, i. e. larger than the atmopheric pressure.

Thus the plate can be supported without physical contact in the range of negative pressure in the graph.

5-2 ANALYSIS OF THEORY

Symbols of some factors in Fig. 5 are designated as shown in Fig. 32, i. e., as follows :

	in pipe	at opening	at any point	at exit of flat surface
radius	kR	kR	rR	R
pressure	P_2	P_1	P	P_0
speed	v_2	v_1	v	v_0
gap		h	h	h

Using equation of continuity,

$$2\pi Rhv_0 = 2\pi(rR)hv = 2\pi(kR)hv_1 = \pi(kr)^2 v_2 \qquad (1)$$

$$\therefore \quad v = \frac{1}{r}v_0 , \quad v_1 = \frac{1}{k}v_0 , \quad v_2 = \frac{2h}{k^2R}v_0 \qquad (2)$$

Designating the density of fluid as ρ (1.3 kg/m^3 in the case of air) and the loss coefficient of contraction as e_v (about 0.3 in the case of air), applying Bernoulli's theorem at the entry of the flat surface,

$$\frac{1}{2}(v_1^2 - v_2^2) + \frac{1}{\rho}(P_1 - P_2) + \frac{1}{2}v_1^2 e_v = 0 \qquad (3)$$

Substituting equation (2) to equation (3)

$$\frac{1}{2}\left(\frac{1}{k^2} - \frac{4h^2}{k^4R^2}\right)v_0^2 + \frac{1}{\rho}(P_1 - P_2) + \frac{1}{2}\frac{1}{k^2}v_0^2 e_v = 0 \qquad (4)$$

$$\therefore \quad P_2 - P_1 = \frac{1}{2}\frac{\rho v_0^2}{k^2}\left(1 + e_v - \frac{4h^2}{k^2R^2}\right) \qquad (5)$$

Applying Bernoulli's theorem at a differential part of flat surface

$$d\left(\frac{1}{2}v^2\right) + \frac{1}{\rho}dP + \frac{1}{2}v^2 f \frac{2}{h} d(rR) = 0 \qquad (6)$$

wherein f designates a coefficient of friction, and f is 16/Re in the case of laminar flow.

Equivalent diameter (hydraulic diameter) between flat surfces is

$$d_e = 4 \times \frac{\text{area of cross section}}{\text{wetted perimeter}} = 4 \times \frac{h \times l}{2 \times l} = 2\,h \tag{7}$$

$$\therefore \quad f = \frac{16}{Re} = \frac{8\mu}{h\rho v} = \frac{8\mu r}{h\rho v_0} \tag{8}$$

Substituting equation (8) to equation (6)

$$d\left(\frac{1}{2}v^2\right) + \frac{1}{\rho}\,d\,P + \frac{8\mu v_0}{\rho h^2}\,\frac{d(rR)}{r} = 0 \tag{9}$$

Integrating this equation

$$\frac{1}{2}\,(v_0^2 - v^2) + \frac{1}{\rho}\,(P_0 - P) - \frac{8\mu v_0}{\rho h^2} R \ln r = 0 \tag{10}$$

$$P_0 - P = \frac{1}{2}\,\rho v_0^2 \left(\frac{1}{r^2} - 1\right) + \frac{8\mu v_0}{h^2} R \ln r \tag{11}$$

At the entry of the flat surface, equation (11) is

$$P_0 - P_1 = \frac{1}{2}\,\frac{\rho v_0^2}{k^2}\,(1 - k^2) + \frac{8\mu v_0}{h^2} R \ln k \tag{12}$$

Eliminating P_1 from equations (12) and (5)

$$P_2 - P_0 = \frac{1}{2}\,\frac{\rho v_0^2}{k^2}\left(e_v - \frac{4h^2}{k^2R^2} + k^2\right) - \frac{8\mu v_0^2}{h^2} R \ln k \tag{13}$$

The value of v_0 can be obtained by knowing $P_2 - P_0$ from this equation (13). Force acting on pipe part upwardly is

$$F_1 = \pi\,(k\,R)^2\,(P_0 - P_2) \tag{14}$$

Force acting on flat surface part upwardly is

$$\begin{aligned} F_2 &= \int_{kR}^{R} (P_0 - P)\; 2\pi\,(r\,R)\; d\,(r\,R) \\ &= \pi R^2 \int_{k}^{1} (P_0 - P)\; d\,(r^2) \end{aligned} \tag{15}$$

Substituting equation (11) to equation (15) and integrating

$$F_2 = -\pi R^2 \left[\frac{1}{2}\rho v_0^2 (\ln k^2 + 1 - k^2) + \frac{4\mu v_0^2}{h^2}(k^2 \ln k^2 - k^2 + 1) \right] \qquad (16)$$

Force acting all parts is

$$F = F_1 + F_2$$
$$= -\pi R^2 \left[k^2 (P_2 - P_0) + \frac{1}{2}\rho v_0^2 (\ln k^2 + 1 - k^2) + \frac{4\mu v_0^2}{h^2}(k^2 \ln k^2 - k^2 + 1) \right]$$

(17)

Substituting v_0 found from equation (13) to equation (17), F can be found.

Fig. 33 shows measured values and values calculated by equation (17) of F (intersecting the axis of abscissas) and measured values of P_2 (not intersecting the axis of abscissas) in the conditions of

Fluids 6, 7 air

Static pressure P_{20} at opening 5 when the opening 5 is closed

350 mmAq, 450 mmAq, 550 mmAq

Inner diameter (2kR) of derivery pipe 3 19 mm.

In the drawing solid lines of F show measured values, and broken lines show the calculated values of F assuming e_v as 0.3. The drawing shows that there are some differences between measured values and calculated values, but these two groups of curves have the same tendency.

6 EFFECT OF THE PRESENT INVENTION

In the method disclosed in my Japanese patent No. 40343/1976 as shown in Figs. 1 and 2, the combination of suction pipe and delivery pipe was essential to support a plate without physical contact.

In the methods disclosed in my prior Japanese patent application No. 71950/1985 and in the present invention, a plate with flat upper surface can be supported near and under the opening of delivery pipe by providing a flat surface extending from the opening of delivery pipe, and the plate can be conveyed with the apparatus when some stoppers are provided extending below the periphery of the flat surface. In these methods the plate having a flat upper surface can be conveyed to the horizontal direction with the apparatus by moving the apparatus.

In the aforesaid prior application, delivered air 7 is delivered from the gap between the flat surface 11 and the plate 8, the air 7 disturbs the atmosphere and the plate 8 is in danger of being stained with minute particles of dust. In the present invention, the delivered air 7 from the gap between the flat surface 11 and the plate 8 is immediately inhaled into the suction pipe 1 and does not spread into the atmosphere, dusts in room cannot be blown up and attach on the plate.

Two fans may be used, one for delivering the air 7 in the delivery pipe 3 and another for inhaling the air 6 into the suction pipe; or only one fan may be used for both delivering and inhaling. If only one fan is used, the flow of air forms a closed circuit, i. e., delivery pipe 3 to suction pipe 1 to fan to delivery pipe 3 (but a little atmospheric air can enter the circuit from the gap between the stopper 12 and the plate 8), and little dust can enter into the circulating air from atmosphere.

When starting the operation of supporting a plate, it is not preferable to move the opening 5 of delivery pipe 3 near the plate 8 after starting the fan, as the delivered air disturbs the surrounding atmosphere, but it is preferable to start the fan after the opening 5 has been near the plate 8.

In the Examples 5 and 6, as the flat surface 11 is provided with channels 13, the flow of the fluid in the gap between the flat surface and the plate is rendered more uniform, and cannot arouse aireddy, the static pressure of air in the gap between the flat surface and the plate cannot change, up-and-down vibration of the plate is completely prevented. When the flat surface 11 is provided with channels 13 curved and/or inclined from the radial direction, the plate can be supported and/or conveyed further stably by gyroscopic effect, as the floating plate rotates by the circling flow of fluid in the gap between the flat surface and the plate.

The present invention is extremely effective for conveying and/or handling of plates, such as semiconductor wafer, magnetic disc, mirror, which should not be marred or stained and cannot be touched with hand or gripper, in their producing or packing process.

CLAIMS:

1. Method of supporting and/or conveying a plate (8) with fluid without physical contact, comprising

providing a flat surface (11) extending at opening (5) of a delivery pipe (3) to the substantially perpendicular direction to the flow direction of fluid (7) in said pipe (3),

providing a ring-shaped or annular inhaling opening (4) of a suction pipe (1) around said flat surface (11),

the lower periphery of the outer wall of the outer pipe extending lower than said flat surface to form a stopper (12),

moving the openings (4) and (5) near the plate 8,

delivering said fluid (7) from said delivery pipe (3),

inhaling said fluid in said inhaling opening (4),

to support the plate (8) near and at a constant distance from said flat surface (11) without physical contact therewith.

2. Method of supporting and/or conveying a plate (8) with fluid without physical contact, comprising

providing a flat surface (11) extending at opening (4) of an inhaling pipe (1) to the substantially perpendicular direction to the flow direction of fluid (6) in said pipe (1),

providing a ring-shaped or annular opening (5) of a delivery pipe (3) around said flat surface (11),

the lower periphery of the outer wall of the outer pipe extending lower than said flat surface to form a stopper (12),

moving the openings (4) and (5) near the plate (8),

delivering said fluid (7) from said delivery opening (5),

inhaling said fluid in said inhaling opening (4),

to support the plate (8) near and at a constant distance from said flat surface (11) without physical contact therewith.

3. Method according to claim 1 or 2, in which channels (13) are provided radially on the flat surface (11).

4. Method according to claim 3, in which the channels (13) are

curved and/or inclined from the radial direction of the flat surface (11).

5. Method according to any of claims 1 to 4, in which both the opening (4) of the suction pipe (1) and the opening (5) of delivery pipe (3) are of ring shape or annular, the inner edge of the inner pipe and the outer edge of the outer pipe extending lower than the flat surface (11) to form stoppers (12a, 12b).

6. Method according to any of claims 1 to 5, in which the suction pipe (1) and the exhaust pipe (3) are put together to form a handle (15).

Fig. 1
PRIOR ART

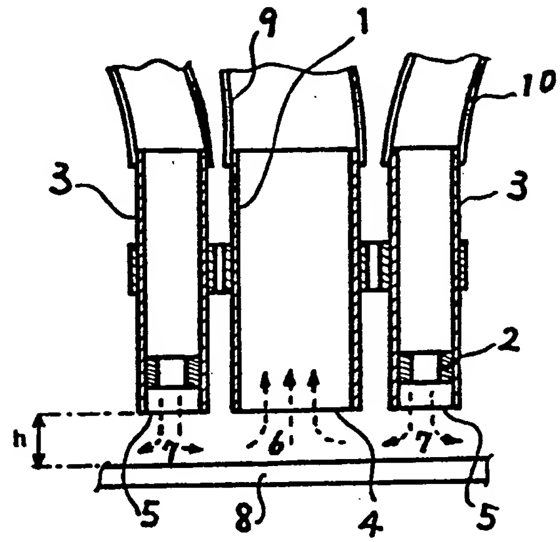

Fig. 2
PRIOR ART

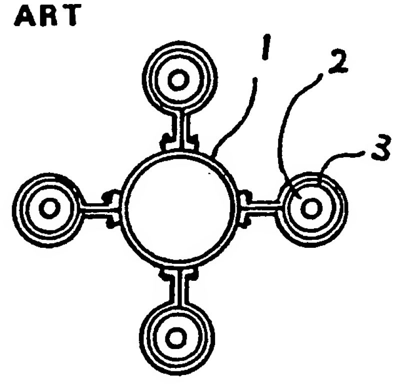

Fig. 3
PRIOR ART

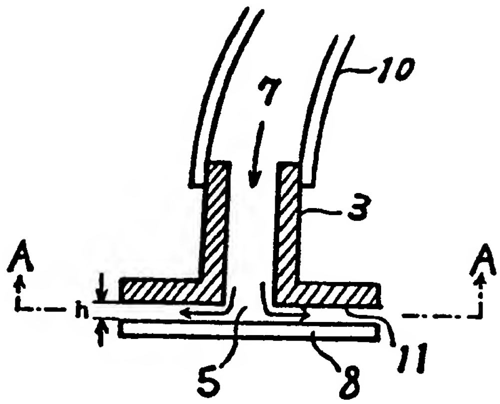

Fig. 4
PRIOR ART

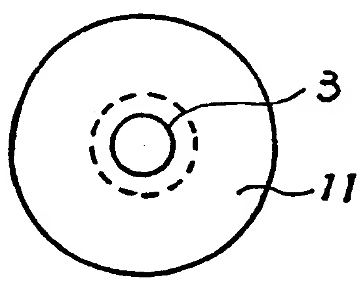

Fig. 5

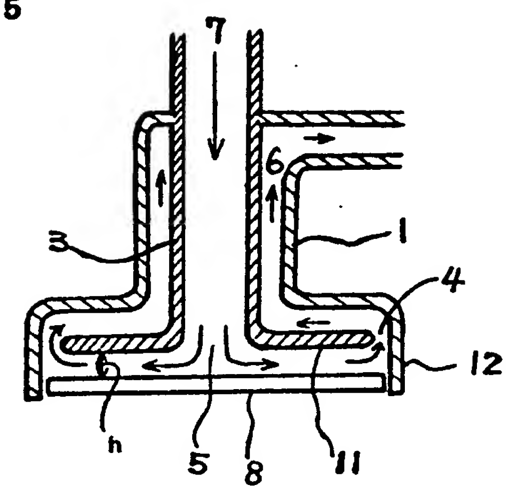

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Fig. 6

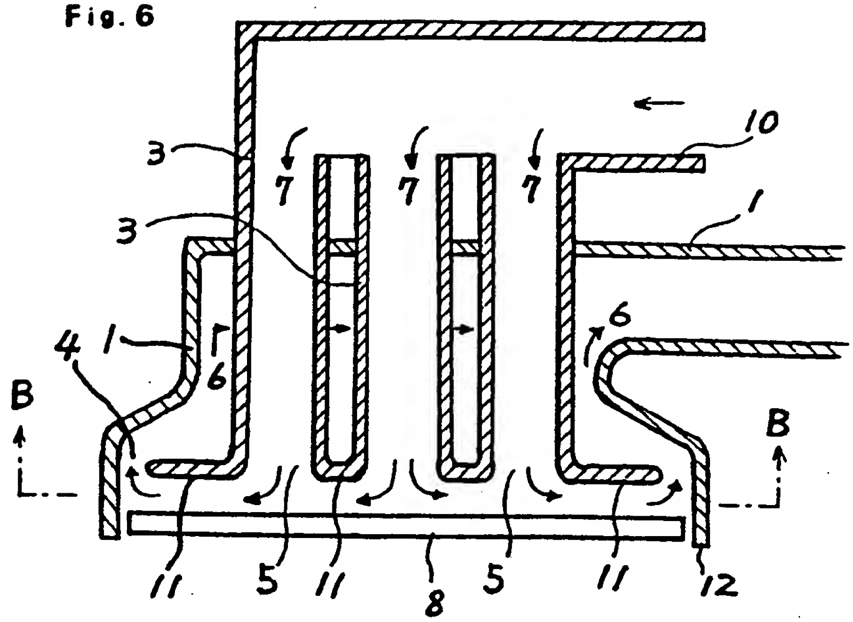


Fig. 7

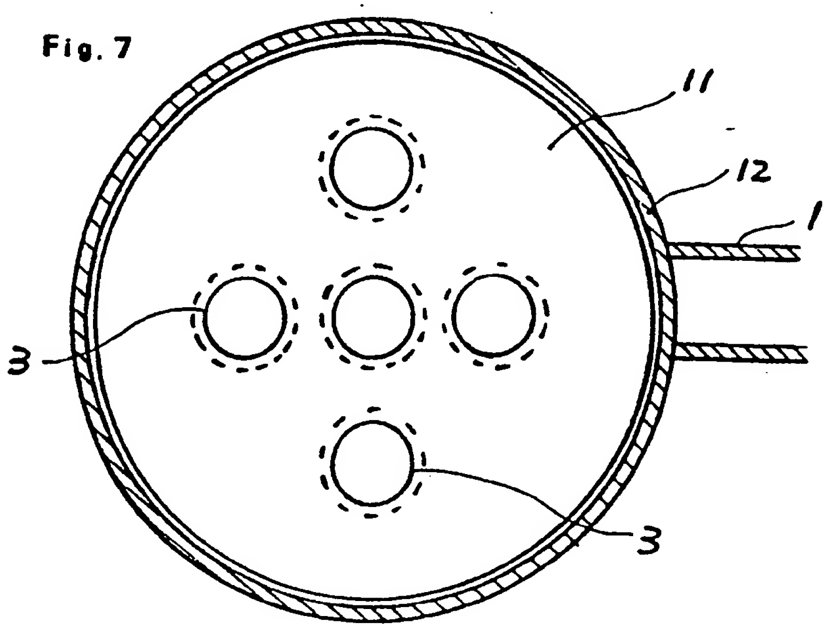


Fig. 8

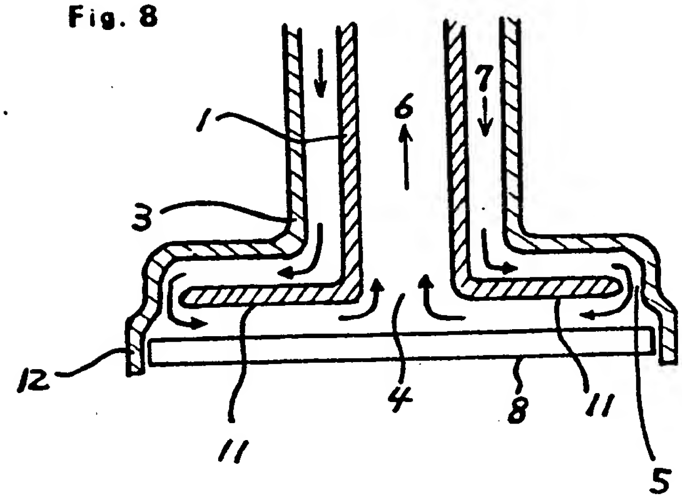


Fig. 9

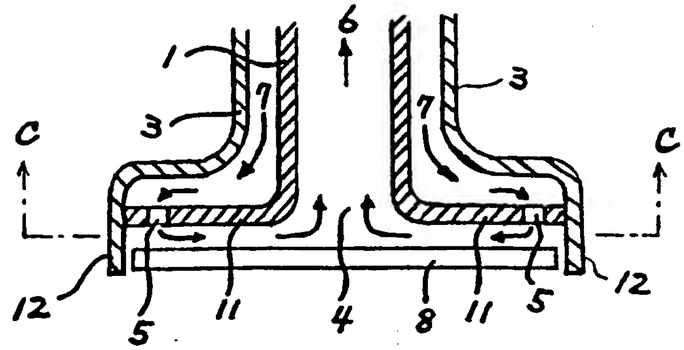


Fig. 10

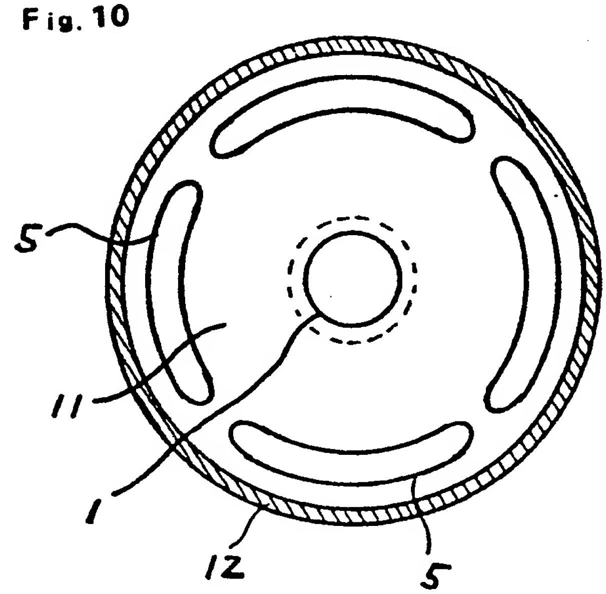


Fig. 11

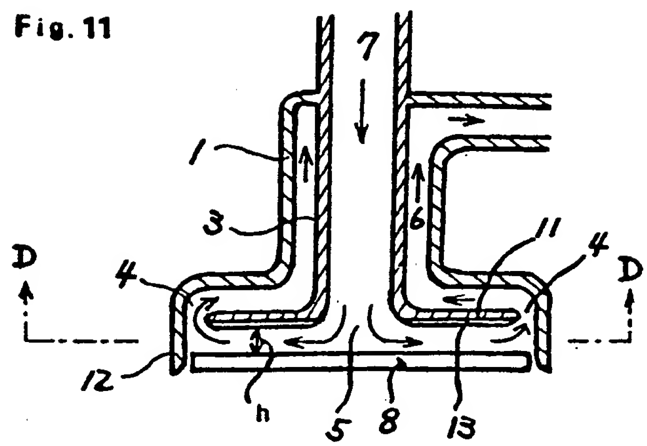


Fig. 12

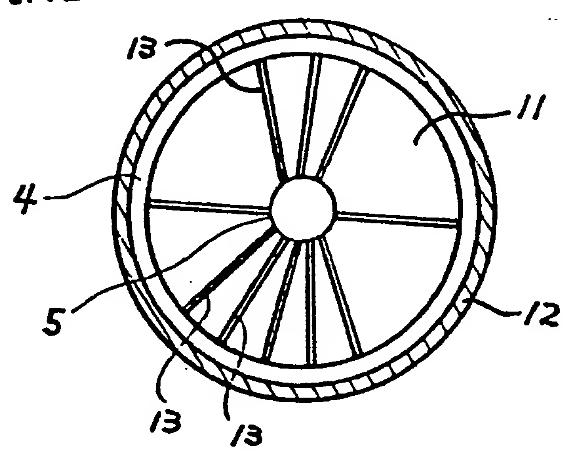


Fig. 13

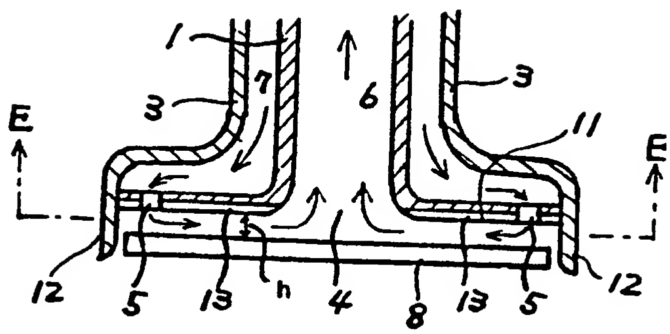


Fig. 14

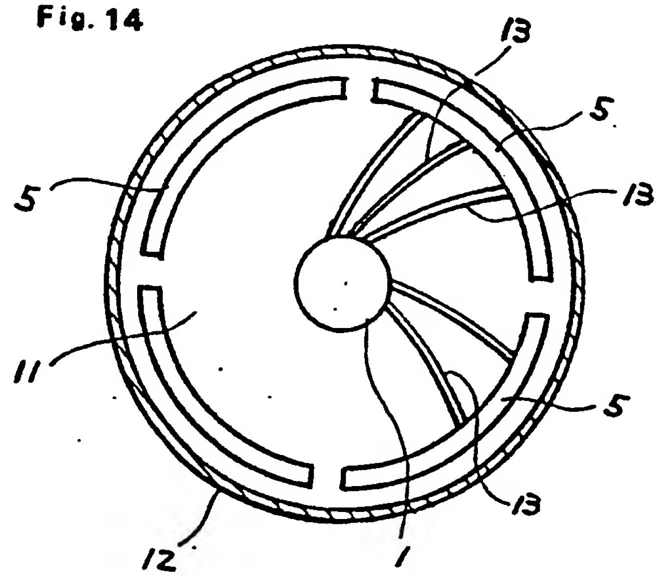


Fig. 15

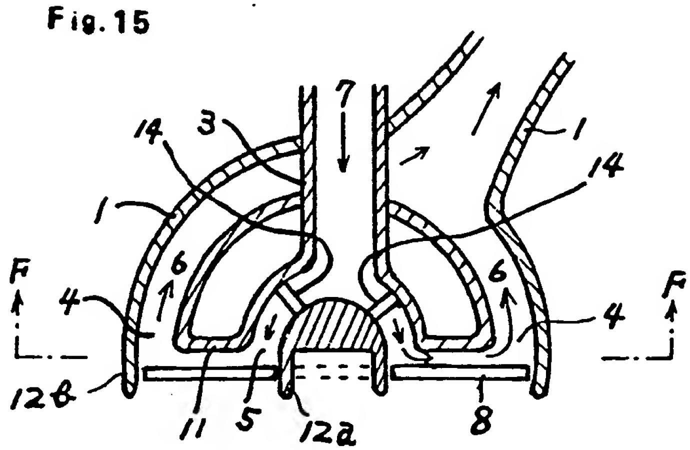


Fig. 16

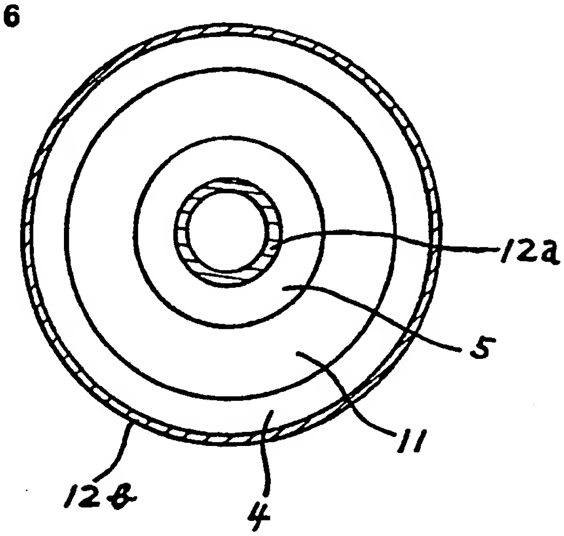


Fig.17

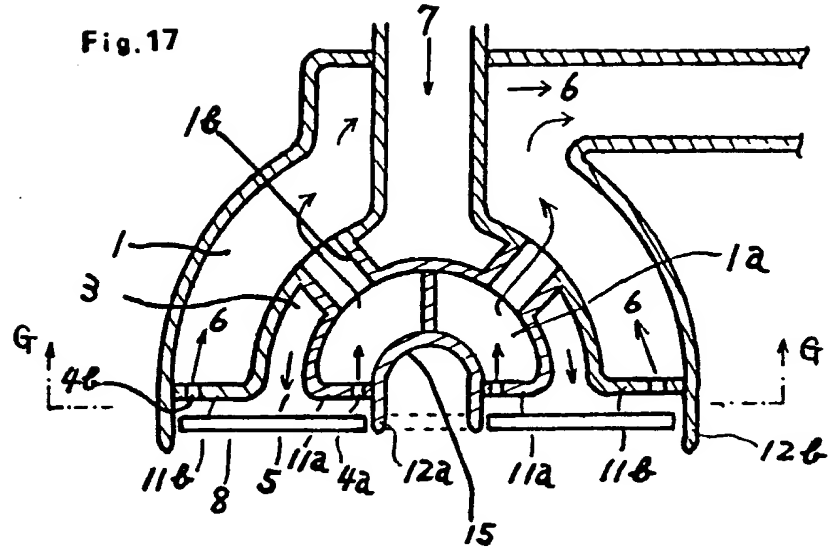

7
6
1b
1
1a
3
6
6
G
4b
G
11b
8
5
11a
4a
12a
11a
11b
12b
15

Fig.18

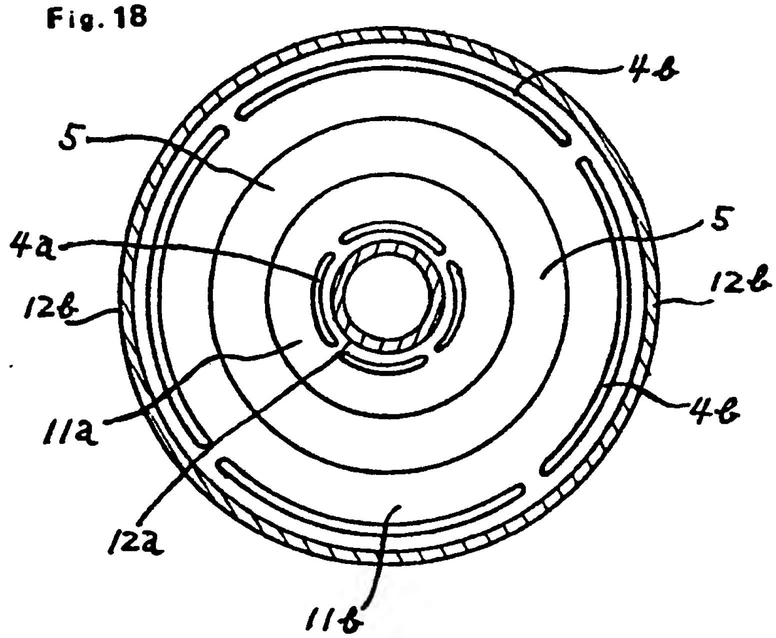

4b
5
5
4a
12b
12b
4b
11a
12a
11b

Fig. 19

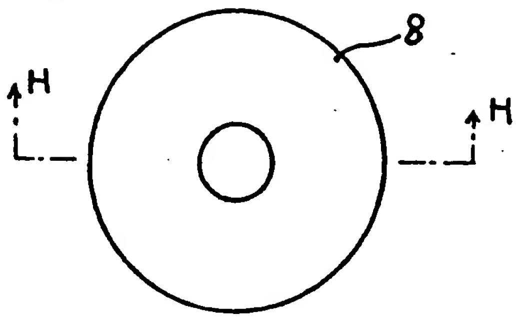


Fig. 20

Fig. 21

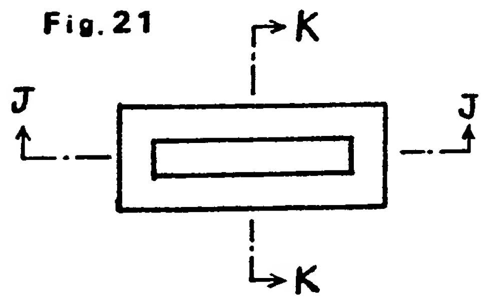
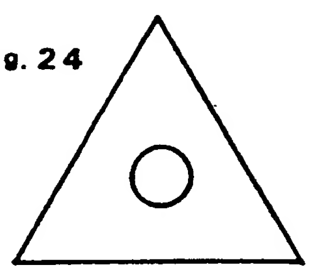


Fig. 23

Fig. 22

Fig. 24



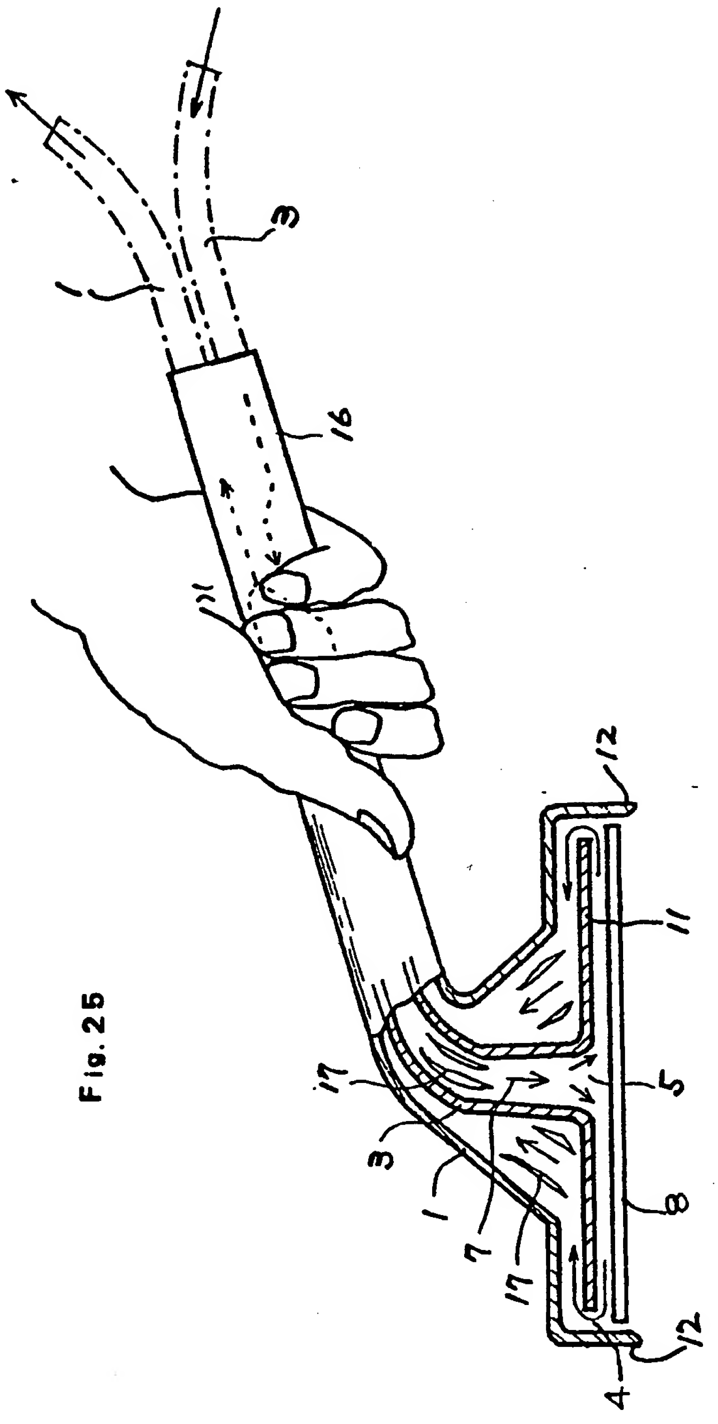


Fig. 25

Fig.26

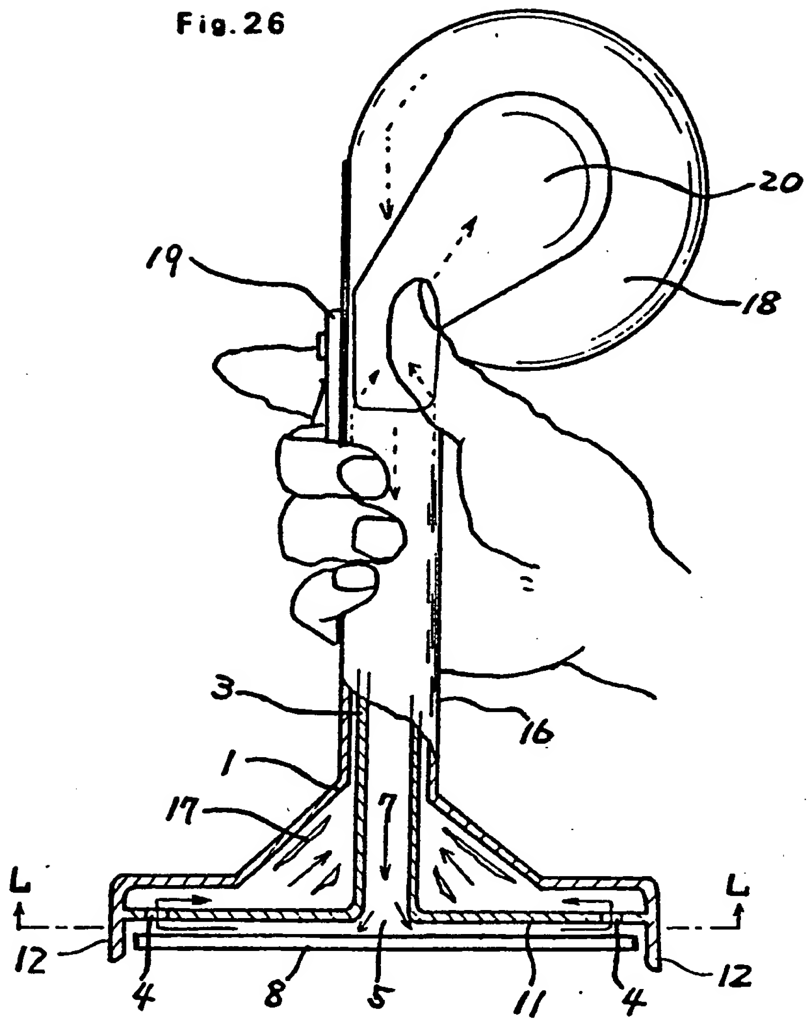


Fig.27

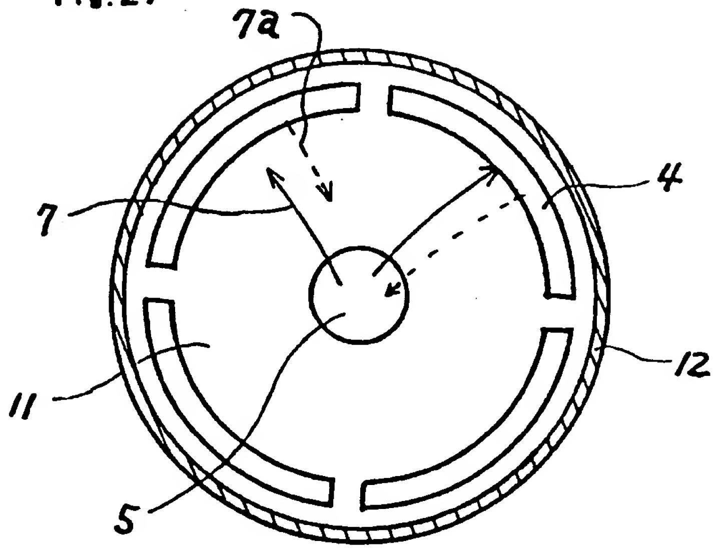


Fig.28

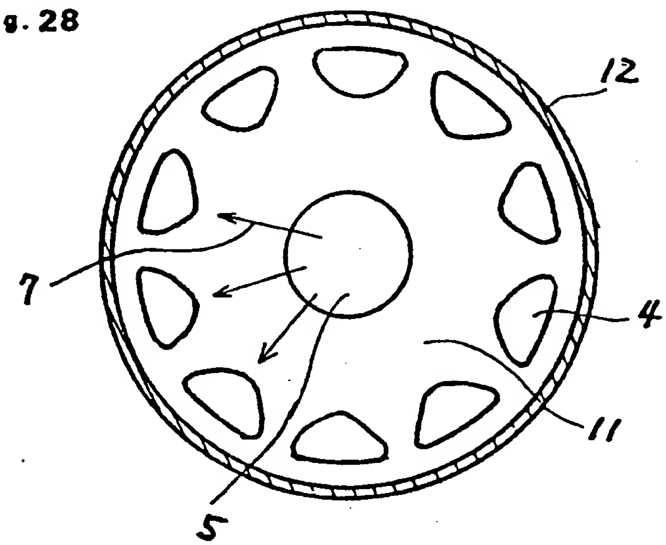


Fig. 29

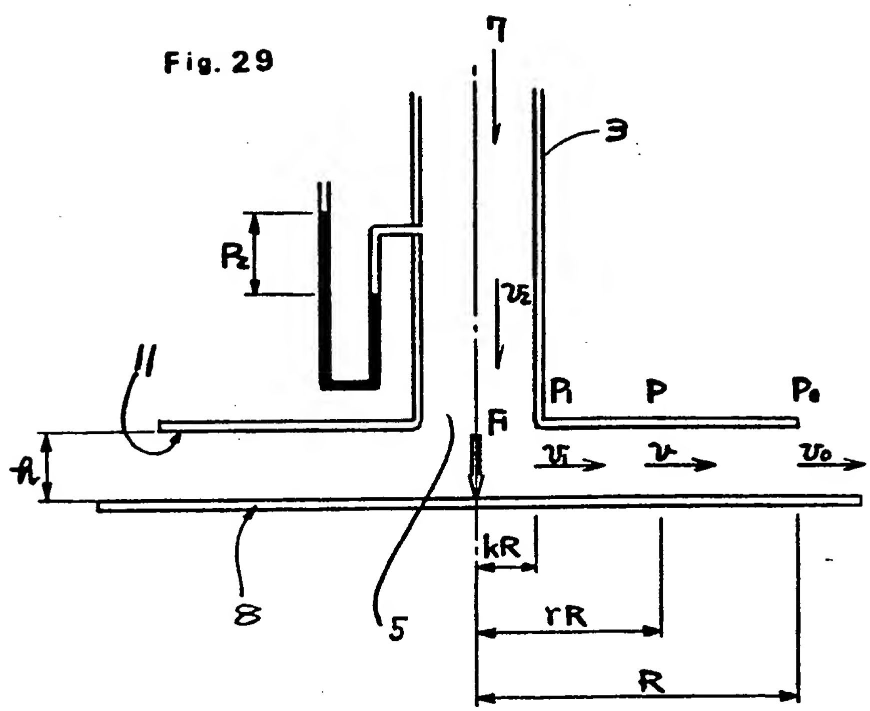
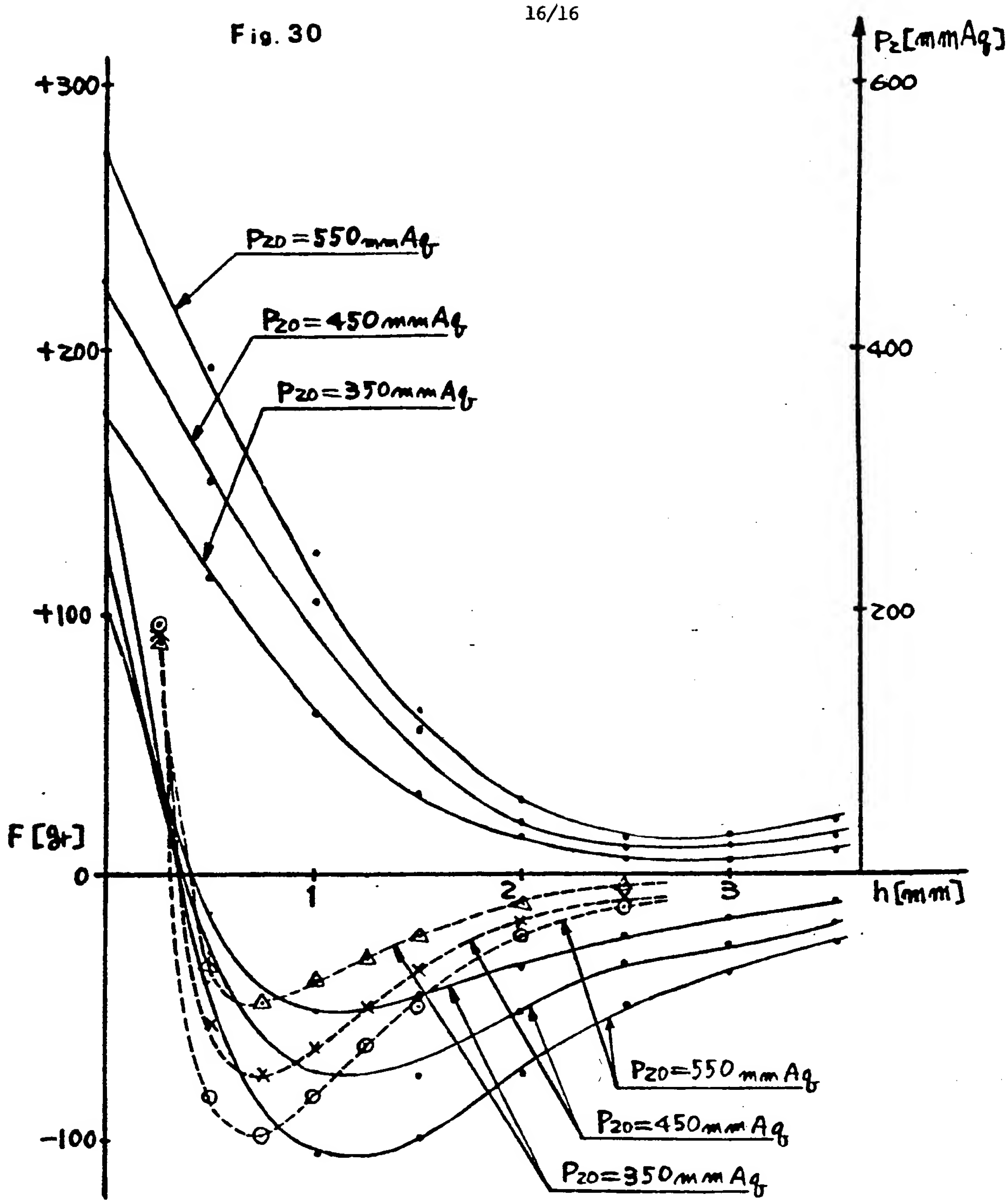


Fig. 30



F [gr]
+300
+200
+100
0
-100
P₂ [mmAq]
600
400
200
h [mm]
1
2
3
P_{20}=550mmAq
P_{20}=450mmAq
P_{20}=350mmAq
P_{20}=550mmAq
P_{20}=450mmAq
P_{20}=350mmAq

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European Patent Office

EUROPEAN SEARCH REPORT

Application number

EP 86 30 3061

Category	DOCUMENTS CONSIDERED TO BE RELEVANT Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
X	US-A-3 466 079 (MAMMEL) * column 4, lines 16-70; figures 4-7 *	1	B 65 G 47/91 H 01 L 21/68 H 05 K 13/00
A		5,6	
X	IBM TECHNICAL DISCLOSURE BULLETIN, vol. 22, no. 8A, January 1980, pages 3370-3371; R.D. COLES "Self-centering non-contact pick-up"	2	
A	GB-A-2 091 698 (PHILIPS ELECTRONIC AND ASSOCIATED INDUSTRIES LTD.) * page 1, line 92 - page 2, line 8; figure 1 *	1	TECHNICAL FIELDS SEARCHED (Int. Cl.4)
A	US-A-3 523 706 (LOGUE) * column 4, lines 43-63 *	1,4	B 65 G 47/00 B 65 H 3/00 B 66 C 1/00 H 01 L 21/00 H 05 K 13/00
A	DE-A-1 531 192 (FA. HORST GERLACH) * page 9, lines 12-16; figure 2 *	1	
A	PATENT ABSTRACTS OF JAPAN, vol. 7, no. 255 (E-210)[1400], 12th November 1983; & JP - A - 58 141 536 (SANYO DENKI K.K.) 22-08-1983	1,3	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
BERLIN	24-07-1986	SIMON J J P.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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E : earlier patent document, but published on, or after the filing date
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L : document cited for other reasons

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